

DESCRIPTION

The models 210 and 211 are chopper stabilized operational amplifiers which combine exceedingly low offset, drift and long term stability with high open loop gain, wide bandwidth, high slewing rate and fast overload recovery — all at nominal cost. Both models are identical in design and differ only in their offset, drift and input noise specifications. These specifications are lowest in the Model 210. Specifically, the Model 210 offers voltage drift and current drift of $\pm 0.5 \mu\text{V}/^\circ\text{C}$ and $\pm 1 \text{pA}/^\circ\text{C}$ as compared to $\pm 1 \mu\text{V}/^\circ\text{C}$ and $\pm 3 \text{pA}/^\circ\text{C}$ for the Model 211. Long term drift at constant temperature is typically less than $1 \mu\text{V}/\text{day}$ for both models.

The low cost and high performance of the 210 and 211 provide an attractive alternative to high performance differential type amplifiers. This is true because voltage offset of differential types is highly sensitive to thermal gradients, and current drift is typically 100 times greater than in the 210/211. Initial offsets of only $100 \mu\text{V}$ and 100pA (150pA for the 211) often eliminate the need for the optional external trim balance potentiometer.

Due to the relatively high chopping frequency, low frequency noise for the 210, only $5 \mu\text{V}$ (peak to peak), is lower than most chopper type amplifiers. A built-in chopper drive circuit, running at about 150Hz , operates directly from the $\pm 15 \text{VDC}$ supply, eliminating the need for external AC excitation.

Packaged in a rugged, 3 cubic inch, epoxy encapsulated module, both models can be soldered directly onto printed circuit cards along with the external feedback components or plugged into optional mounting sockets. Silicon semiconductors are used throughout.

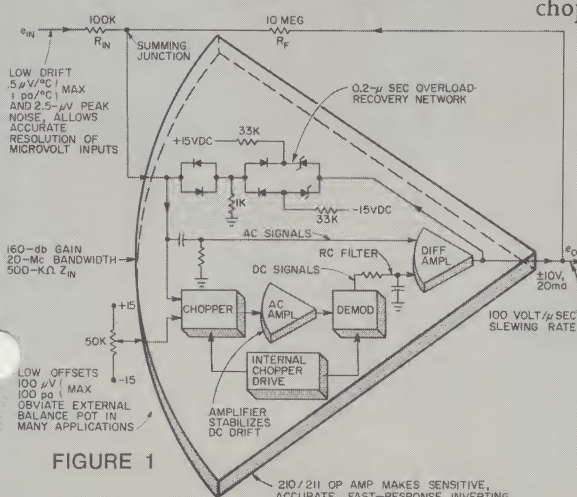


FIGURE 1

The output, which is rated for ± 10 volts and 20mA , is completely protected against short circuits and the input can be overloaded to ± 15 volts without damage.

FAST OVERLOAD RECOVERY

Most chopper amplifiers suffer overload recovery times of several seconds following an input overdrive. This problem has been solved in the 210 and 211 by including a clamping circuit which prevent the amplifier output from saturating. Thus, the amplifier will recover within $0.2 \mu\text{sec}$ after an input overdrive, which is a considerable improvement even compared to differential type amplifiers.

FAST RESPONSE

In addition to low drift, the Models 210 and 211 feature exceptionally fast response. Unity gain bandwidth is 20MHz , while full output voltage is obtained to 500kHz . Very fast slewing rates to $100 \text{VOLTS}/\mu\text{sec}$ are achieved. DC voltage is 160dB and, equally important, gain is maintained above 90dB at frequencies up to 10kHz . Consequently, the transient response will settle to high accuracy very rapidly — a useful feature in fast A-D converters and pulse amplifiers.

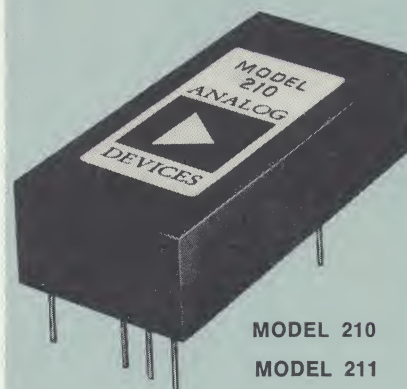
OPERATION

The philosophy of operation consists of dividing the incoming voltage and feedback signal into high and low frequency components. All frequencies above a few cycles per second are fed directly into the inverting (−) input of the differential amplifier which has very fast response characteristics. The very low frequency signals pass through a low pass filter, are chopped, amplified by an AC amplifier and demodulated before entering the non-inverting (+) input of the differential amplifier. This effectively divides the drift of the differential amplifier (referred to the input) by the gain of the chopper amplifier, with the result that the predominant contributions to drift are those of the low level chopper. Note that the chopper technique results in a single ended input amplifier which can only be used in the inverting configuration unless floated power supplies are employed.

MODEL 210/211 CHOPPER STABILIZED OPERATIONAL AMPLIFIERS

FEATURES

Low Drift	$0.5 \mu\text{V}/^\circ\text{C}$ $1 \text{pA}/^\circ\text{C}$
High Slewing Rate	$100 \text{V}/\mu\text{sec}$
Wide Bandwidth	20MHz
Fast Overload Recovery	$0.2 \mu\text{sec}$
Long term Stability	$1 \mu\text{V}/\text{day}$
Voltage gain	10^8
Low Noise	$5 \mu\text{V}(\text{p-p})$
Built in Chopper Drive	



MODEL 210
MODEL 211

APPLICATIONS

Precision Integrators
Micro Volt D.C. Amplifier
Precision Current Sources
Precision Voltage Sources
A-D Converter
Low Current Amplifier
Low Level Voltage Comparator

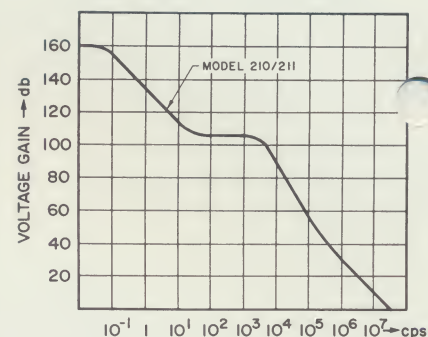


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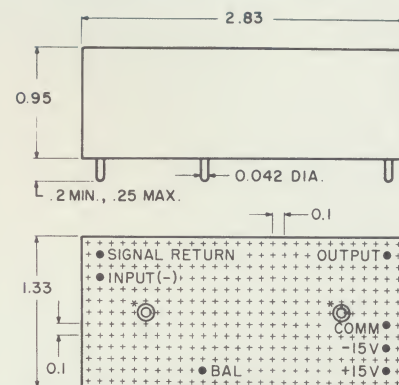
SPECIFICATIONS (typical at 25°C and ±15VDC unless otherwise noted)

	MODEL 210	MODEL 211
OPEN LOOP VOLTAGE GAIN		
dc , rated load,min .		10 ⁸
RATED OUTPUT		
Voltage		±10V
Current, min.		20ma
FREQUENCY RESPONSE		
Unity gain, small signal		20mHz
Full output response, min.		500KHz
Slewing rate		100V/μsec
Overload recovery		0.2μsec
INPUT VOLTAGE OFFSET		
Initial offset @25°C, max.		±100μV
Avg. vs. temp. (10 to 85°C), max.	±.5μV/°C	±1μV/°C
(-25 to 10°C), max.	±1μV/°C	±2μV/°C
vs. supply voltage		10μV/‰
vs. time		1μV/day
INPUT CURRENT OFFSET		
Initial offset @25°C, max.	±100pa	±150pa
Avg. vs. temp. (-25 to 85°C), max.	±1pa/°C	±3pa/°C
vs. supply voltage		±10pa/‰
INPUT CHARACTERISTICS		
(single ended, inverting)		
Input Impedance, DC, open loop		500K ohms
Max. safe input signal		±15V
Input voltage noise, DC to 1cps, p to p	5μV	10μV
5 to 10KHz , rms		10μV
Input current noise, DC to 1 cps, p to p		10pa
TEMPERATURE RANGE		
Specification		-25 to +85°C
Operating		-55 to +85°C
Storage		-65 to +100°C
POWER SUPPLY		
Voltage		±(15 to 16) VDC
Current, quiescent		+40ma, -10ma
PRICE		
(1-9)	\$157	\$120
(10-24)	\$148	\$114

OPEN LOOP RESPONSE

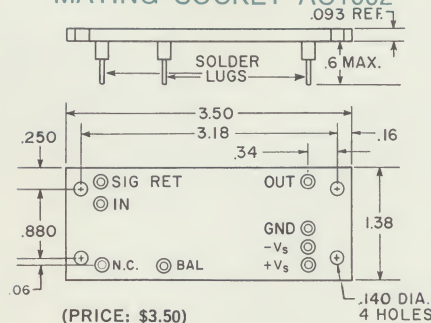


OUTLINE DIMENSIONS

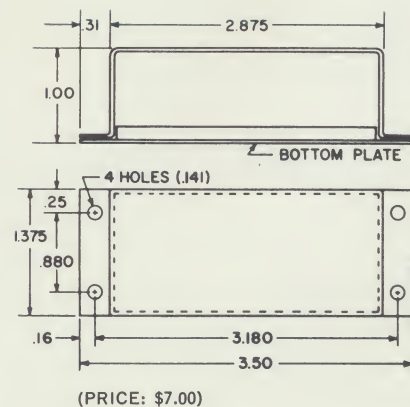


* OPTIONAL HOLD DOWN NUTS AVAILABLE
2-56 NC-2B THDS; 0.10" DEEP

MATING SOCKET AC1002



AC1106 NOISE SHIELD
& HOLD DOWN BRACKET



POWER SUPPLY

Requirements

Rated specifications depend on the supply voltages being in the range from ± 15 to 16 VDC. As the supply voltage drops below ± 15 VDC the overload circuit will not function properly and below 13 to 14 volts the amplifiers' operating specifications are degraded. For best operation, ripple voltage should be no more than a few millivolts and voltage transients should be decoupled as much as possible.

Connections

For proper operation of the Models 210 and 211 the input (+) must be externally connected to the power supply common. Thus a separate wire should go directly from the input (+) to the power supply common to prevent ground loops. The amplifier can be damaged by applying incorrect polarity of supply voltages. Be sure polarities are correct.

INITIAL OFFSET ADJUSTMENTS

Since the Models 210 and 211 have a maximum initial voltage offset of $\pm 100 \mu\text{V}$, external offset adjustments may not be required. In this case the balance terminal of the amplifier should be left open. However, in critical applications the amplifier can be zeroed by connecting an external 50k ohm potentiometer to the balance terminal as shown in Fig. 2.

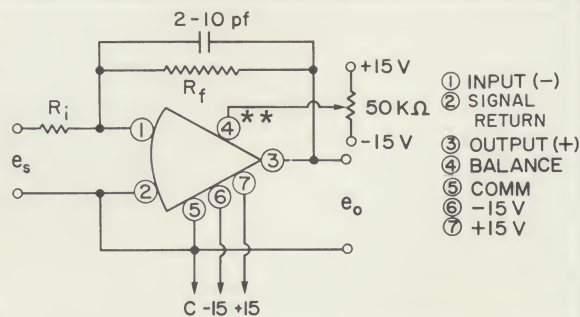


FIGURE 2

For precision integrator or low current applications, the initial offset current can be zeroed with the circuits shown in Fig. 3. The adjustment range of this bias circuit is ± 150 pa.

For a fixed source impedance, voltage or current biasing have an equivalent effect and either technique can be used to zero both initial voltage and current offsets.

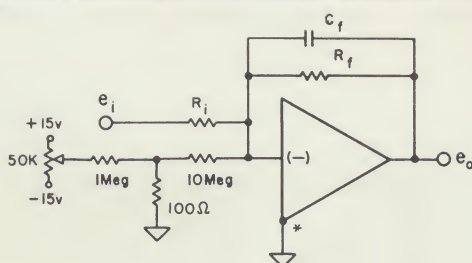


FIGURE 3 — EXTERNAL CURRENT BALANCE

However, for a changing source impedance in critical application, as in the case of opening and shorting the input or in multiplexing the input to various source impedances, then both voltage and current balancing must be used to zero offset voltage and current independently.

WIRING PRECAUTIONS

Remember that the exceptionally low drift and input current specification can be degraded by improper external wiring. Therefore, all lead connections, including those to the power supply, should be made as short as possible. If it is necessary to have long leads to the feedback network, connect the stabilizing capacitor, C_f , directly from the output terminal to the input terminal.

Leakage resistance from the summing junction to an external voltage potential is also particularly critical. For example, a leakage resistance of 10^{12} ohms between the summing junction and the 15 VDC supply voltage results in 15pA input current. For critical applications such as high quality integrators, leads to the summing junction should be isolated from external voltage potentials by ground potential shielding. Moreover, thermocouple voltages can generate offset voltage drift comparable to that of the amplifier and precautions should be taken to minimize this source of offset potential.

CLOSED LOOP STABILITY

The high frequency performance of the Models 210 and 211 is characterized by a useful small signal bandwidth of up to 20MHz, slewing rate of $100\text{V}/\mu\text{sec}$ and full power response of 500 khz. These specifications are achieved in part by internal phase compensation networks that attenuate the open loop gain faster than 6DB/octave. "Fast rolloff" operational amplifiers require a small feedback capacitor across the feedback resistor in most circuits to provide proper phase margin for stability. For optimum bandwidth, it is suggested that a square wave be applied to the closed loop circuit, and the value of C_f adjusted for the desired transient response at the output. For a range of gains and operational resistances, C_f will vary from one or two pf to perhaps hundreds of pf, although most circuits require five pf.

CAPACITANCE LOADS

Load capacitance, in conjunction with the output impedance of the amplifier can cause oscillations. Fig. 4 shows an isolating circuit suitable for most applications with capacitance loads. Since R_i is inside the feedback loop, low output impedance is maintained.

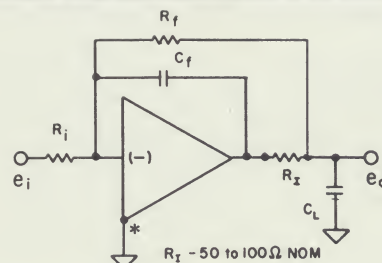


FIGURE 4 — ISOLATING CAPACITANCE LOADS

*DOT DENOTES A CONNECTION TO POWER SUPPLY COMMON

OVERLOAD RECOVERY

An internal fast overload recovery circuit is included in the 210 and 211 to prevent the amplifier output from saturating. Thus the long delays following output saturation which is characteristic of most chopper stabilized amplifiers is avoided. The actual circuit used is shown in Fig. 1. This circuit provides additional feedback current when the amplifier output exceeds the zener plus diode voltage drops. The maximum amount of current that can be fed back is the amplifier's rated output less the load current. Therefore the input overload current must not be allowed to exceed this value.

The proper operation of this circuit depends on the following instructions:

1. Power supply voltage must be a minimum of ± 15 volts for proper operation.
2. All input overload current must be supplied through the feedback network from the amplifier output in order to maintain linear operation. If the input current plus the load current exceeds the amplifier's rated output current, then the overload recovery circuit will not function properly. For example, a 1000 ohm load resistor draws 10ma. Therefore, maximum input overload current cannot exceed 10ma.
3. Maximum overload transient voltages across the input terminals should be limited to ± 50 volts. Due to dissipation limiting, maximum steady state voltage overload to the input should not exceed ± 15 VDC.

OVERCOMING LARGE FEEDBACK RESISTORS

Low level DC amplifier circuits many times require feed-back resistors in the 10 to 1000 megohm range. High value, stable, precision resistors are not readily available. The circuit in Fig 5 shows one way to circumvent the use of very large resistance values. The gain for this circuit is,

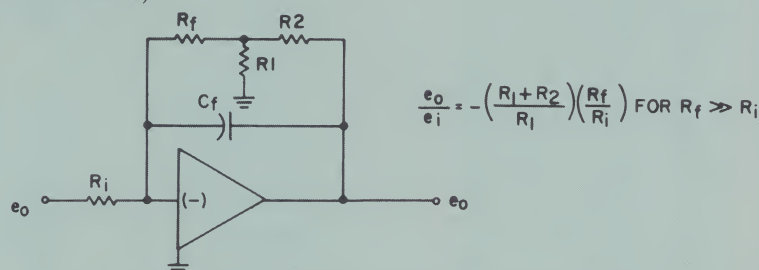


FIGURE 5 — FEEDBACK VOLTAGE DIVIDER

One disadvantage to this technique arises in that voltage drift and noise are increased. This effect can be minimized by using as small a ratio as practical for $(R_1 + R_2)/R_1$.

OTHER LOW DRIFT MODELS

In addition to the Models 210 and 211, other low drift operational amplifiers are available from Analog Devices. The following chart is offered as a quick reference guide in comparing the 210 and 211 to a few of these amplifiers.

MODEL	ADVANTAGES vs. 210/211	DISADVANTAGES vs. 210/211
180B — \$110. (Differential Transistor) 0.75 μ V/ $^{\circ}$ C 2nA/ $^{\circ}$ C 1 μ V — p-p noise	Smaller size and weight/ lower cost/differential input/comparable voltage drift/lower "1/f" voltage noise	Higher long term offset drift/higher current drift/ higher sensitivity to thermal gradients
147C — \$135. (F.E.T. Differential) 1.5pA/ $^{\circ}$ C 2 μ V/ $^{\circ}$ C 0.1pA — p-p noise	Smaller size and weight/ differential input/higher Z _{IN} / lower current noise/ comparable current drift	Higher voltage drift/higher long term offset drift/ higher sensitivity to thermal gradients
202/203 — \$235/215. (Chopper Stabilized) 0.2 μ V/ $^{\circ}$ C 0.5pA/ $^{\circ}$ C	Lower current and voltage drift	Higher price/higher voltage noise

TYPICAL APPLICATIONS

(For more details concerning the following circuits as well as for additional applications request 12 page application manual for 200 series Chopper Stabilized Operational Amplifiers.)

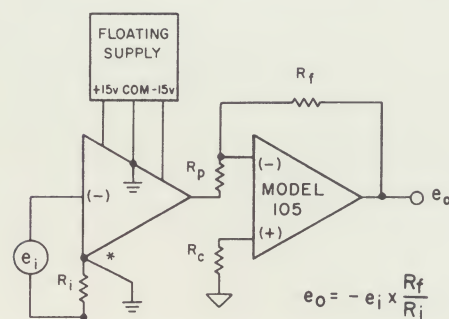


FIGURE 6 — HIGH INPUT IMPEDANCE (INVERTING WITH GAIN)

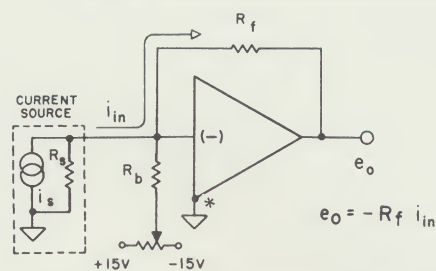


FIGURE 7 — CURRENT to VOLTAGE CIRCUIT (PHOTOMULTIPLIER, etc.)

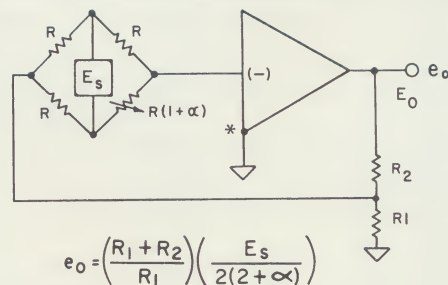


FIGURE 8 — BRIDGE AMPLIFIER (FLOATING BRIDGE SUPPLY)

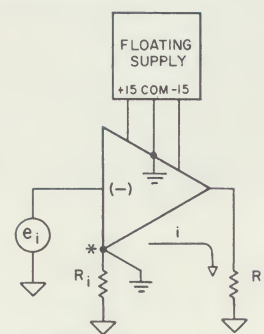


FIGURE 9 — CURRENT SOURCE (FLOATING SUPPLY)



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TWX 710/320-0326

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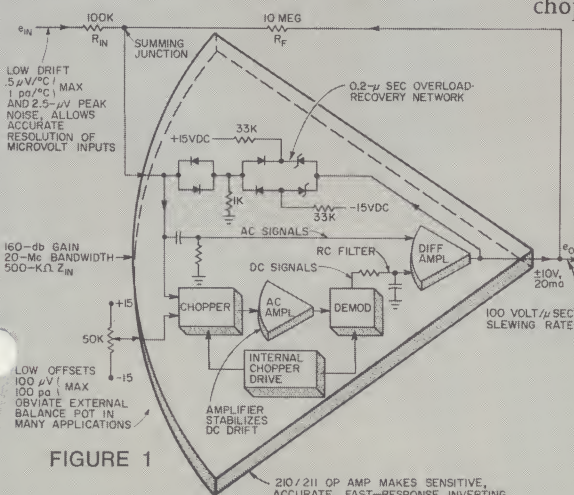


FIGURE 1

The output, which is rated for ± 10 volts and 20mA , is completely protected against short circuits and the input can be overloaded to ± 15 volts without damage.

FAST OVERLOAD RECOVERY

Most chopper amplifiers suffer overload recovery times of several seconds following an input overdrive. This problem has been solved in the 210 and 211 by including a clamping circuit which prevent the amplifier output from saturating. Thus, the amplifier will recover within $0.2 \mu\text{sec}$ after an input overdrive, which is a considerable improvement even compared to differential type amplifiers.

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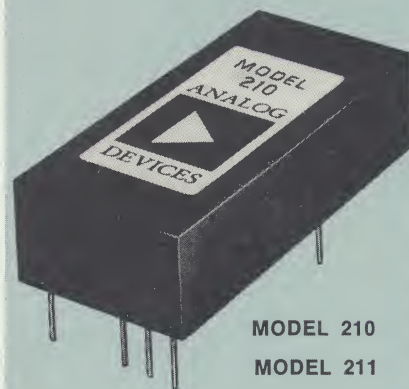
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MODEL 210/211 CHOPPER STABILIZED OPERATIONAL AMPLIFIERS

FEATURES

Low Drift	$0.5 \mu\text{V}/^\circ\text{C}$ $1 \text{pA}/^\circ\text{C}$
High Slewing Rate	$100 \text{V}/\mu\text{sec}$
Wide Bandwidth	20MHz
Fast Overload Recovery	$0.2 \mu\text{sec}$
Long term Stability	$1 \mu\text{V}/\text{day}$
Voltage gain	10^8
Low Noise	$5 \mu\text{V}(\text{p-p})$
Built in Chopper Drive	



MODEL 210
MODEL 211

APPLICATIONS

Precision Integrators
Micro Volt D.C. Amplifier
Precision Current Sources
Precision Voltage Sources
A-D Converter
Low Current Amplifier
Low Level Voltage Comparator

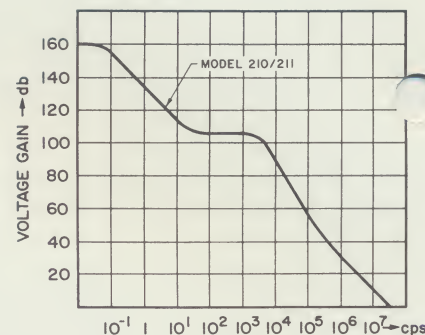


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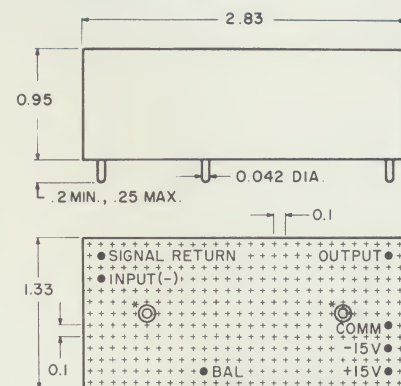
SPECIFICATIONS (typical at 25°C and ±15VDC unless otherwise noted)

	MODEL 210	MODEL 211
OPEN LOOP VOLTAGE GAIN		
dc , rated load,min .		10 ⁸
RATED OUTPUT		
Voltage		± 10V
Current, min.		20ma
FREQUENCY RESPONSE		
Unity gain, small signal		20mHz
Full output response, min.		500KHz
Slewing rate		100V/μsec
Overload recovery		0.2μsec
INPUT VOLTAGE OFFSET		
Initial offset @25°C, max.		±100μV
Avg. vs. temp. (10 to 85°C), max.	±.5μV/°C	±1μV/°C
(− 25 to 10°C), max.	±1μV/°C	±2μV/°C
vs. supply voltage		10μV/°%
vs. time		1μV/day
INPUT CURRENT OFFSET		
Initial offset @25°C, max.	±100pa	±150pa
Avg. vs. temp. (− 25 to 85°C), max.	±1pa/°C	±3pa/°C
vs. supply voltage		±10pa/°%
INPUT CHARACTERISTICS		
(single ended, inverting)		
Input Impedance, DC, open loop		500K ohms
Max. safe input signal		±15V
Input voltage noise, DC to 1cps, p to p	5μV	10μV
5 to 10KHz , rms		10μV
Input current noise, DC to 1 cps, p to p		10pa
TEMPERATURE RANGE		
Specification		− 25 to +85°C
Operating		− 55 to +85°C
Storage		− 65 to +100°C
POWER SUPPLY		
Voltage		±(15 to 16) VDC
Current, quiescent		+ 40ma, − 10ma
PRICE		
(1-9)	\$157	\$120
(10-24)	\$148	\$114

OPEN LOOP RESPONSE

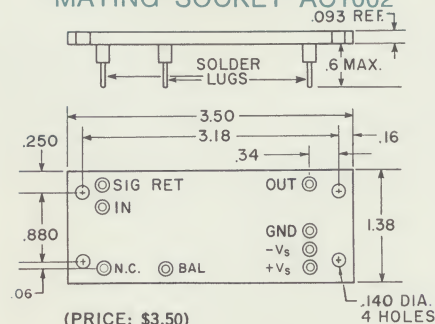


OUTLINE DIMENSIONS



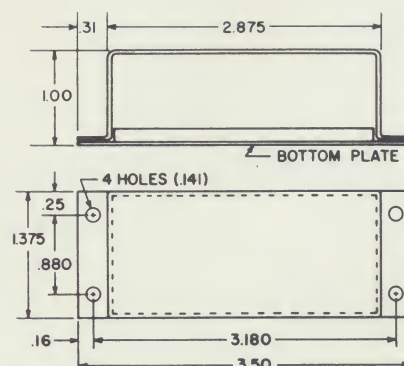
*OPTIONAL HOLD DOWN NUTS AVAILABLE
2-56 NC-2B THDS; 0.10" DEEP

MATING SOCKET AC1002



(PRICE: \$3.50)

AC1106 NOISE SHIELD & HOLD DOWN BRACKET



(PRICE: \$7.00)